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EMPLOYMENT OF ASTEROIDS FOR MOVEMENT SPACE SHIP AND PROBES

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Abstract

At present, rockets are used to change the trajectory of space ships and probes. This method is very expensive and requires a lot of fuel, which limits the feasibility of space stations, interplanetary space ships, and probes. Sometimes space probes use the gravity field of a planet. However, there are only 9 planets in Sour solar system and they are separated by great distances. There are tens of millions of asteroids in outer space. The author offers a revolutionary method for changing the trajectory of space probes. This method uses the kinetic or rotary energy of asteroids, meteorites or other space bodies (small planets, natural planet satellites, etc.). to increase (to decrease) ship (probe) speed up to 1000 m/sec (or more) and to get any new direction in outer space. The flight possibilities of space ships and probes are increased by a factor of millions.

Nomenclature (metric system):

a - relative cross-section area of cable (cable);
A - cross-section area of cable [m^2];
A_0 - initial (near probe) cross-section area of cable [m^2];
g_0 - gravitation at the R_0 [m/s^2];
$g_o = 9.81$ m/s^2 for Earth;
$k = \sigma/\gamma$ – ratio of cable tensile stress to density [nm/kg];
$K = k/10^7$ – coefficient;
n – overload;
r – variable [m];
R - radius from gravity center to the probe [m];
R_0 - radios of planet [m];
R_g - radius of geosynchronous orbit [m];
V - speed of Space Ship about asteroid [m/s];
V_a - initial speed of asteroid about Space Ship [m/s];
ΔV - ship additional speed received from asteroid [m/s]; $\Delta V>0$ if V_a and V have same direction:
W - mass of a cable [kg];
W_r - relative mass of cable (ratio of cable mass to ship mass);
W_s - ship (probe) mass;
σ - (or H) tensile strength [n/m^2];
ω - angular speed of a probe or asteroid [rad/sec];
γ - density of cable [kg/m^3];
$\varphi = \varphi_1 + \varphi_2$, where
φ_1 - angle between velocity vectors of asteroid and probe.
φ_2 – angle between old and new velocity vectors of probe.

Introduction

At present, rockets are used to carry people, payloads into space, or to deliver bombs over long distances. This method is very expensive, and requires a well-developed industry, high technology, expensive fuel, and complex devices [1].

Other then rockets, methods to reach the space speed: space elevator [2], the tube rocket [7] and the electromagnetic system The space elevator requires in very strong nanotubes, as well as, rocket and high technology for initial development. The tube rocket [7] requires in more detailed research.

There are many small solid objects in the Solar System called asteroids. The vast majority are found in a swarm called the asteroid belt, located between the orbits of Mars and Jupiter at average distance of 2.1 to 3.3 astronomical units (AU) from the Sun. Scientists know of approximately 6000 large asteroids of diameter 1 kilometer or more, and of millions of small asteroids with diameter 3 meters or more. Ceres, Pallas, and Vesta are the three largest asteroids, with diameters of 785, 110 and 450 km (621, 378, and 336 mi), respectively. Others range all the way down to meteorite size. In 1991 the Galileo probe provided a first close-up view of an asteroid Caspra; although the Martian moons (already seen close up) may also be asteroids, captured by Mars. There are many small asteroids, meteorites, and comets

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outside the asteroid belt. For example, scientists know of 1,000 asteroids of diameter larger than one kilometer located near the Earth. Every day one-ton meteorites with mass over 8 kg fall on the Earth. The orbits of big asteroids are well known. The small asteroids (from 1 kg) may be located and their trajectory is determined by radio and optical devices of a distance of hundreds of kilometers.

Most planets, such as Mars, Jupiter, Saturn, Uranus, and Neptune have many small Moons, which can be used for the proposed space transportation method.

Most asteroids consist of carbon-rich minerals, while most meteorite are composed of stony-iron.

The author's idea is to utilize the kinetic energy of asteroids or meteorites, to change the trajectory and speed of space ships (probes). Any space bodies more than 10% of a ship's weight (probe), but here we consider mainly body diameter 2 meters (4 feet) or larger. In this case the mass (20-100 tons) of space body (asteroid) is some ten times more than the probe's mass (1 ton, 2000 LB) and we can disregard the probe mass.

Method and Equipment

. The **method** includes of the following main steps:

(a) Searching by a locator, telescope (or finding in catalog) an asteroid and determining its main parameters (location, mass, speed, direction, rotation). Selecting the appropriate asteroid. Computing the needed position of the ship about asteroid.

(b) Correcting the ship's trajectory for getting a needed position. Converging of the ship with the asteroid.

(c) Connecting of a space apparatus (ship, station, and probes) to a space body (planet, asteroid, moon, satellite, meteorite, etc.) by a net, anchor, and a light strong rope (cable), when the ship has minimum distance to asteroid.

(b) Obtaining the necessary apparatus position by turning the apparatus around the space body and changing the length of the connection rope.

(c) Disconnecting the space apparatus from the space body.

The **equipment** for changing a spacecraft trajectory include:

(a) A light strong rope.

(b) A device to observe/measure the trajectory of the spacecraft with respect to the space body.

(c) A device for spacecraft guidance and control.

(d) A device for the connection, delivery, control, and disconnection and spooling of the rope.

Description of the Innovation

The following describes the general facilities and process for a natural space body (asteroid, meteorite, or small planet) having a small gravitational force to change the trajectory and speed of a space apparatus

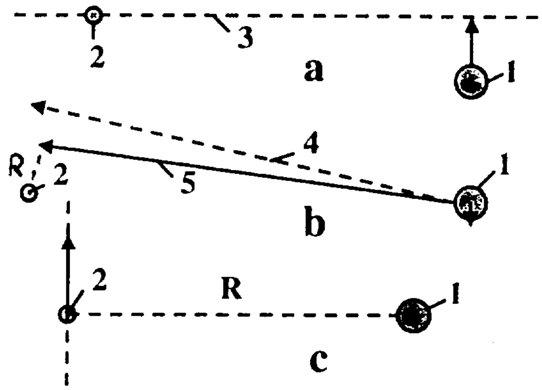

Fig.1. Preparing for employment of asteroid. Notations: 1 - space ship, 2 - asteroid, 3 - plane of maneuver. a) Reaching of the plane of maneuver; b) Correction of flight direction and getting a requested radius; c) Connection to asteroid.

Figs.1a,b,c show the preparations for using a natural body to change the trajectory of a space apparatus. For example, the natural space body **2** which flys in same direction as the apparatus (perpendicular to the sketch list, fig.1a). The ship wants to make a maneuver (change direction or speed) in plane **3** (perpendicular to the sketch list), the position of the apparatus is corrected and positioned in plane **3**. It assumes the space body has more mass than the apparatus, and the space body speed has about the same velocities as the apparatus.

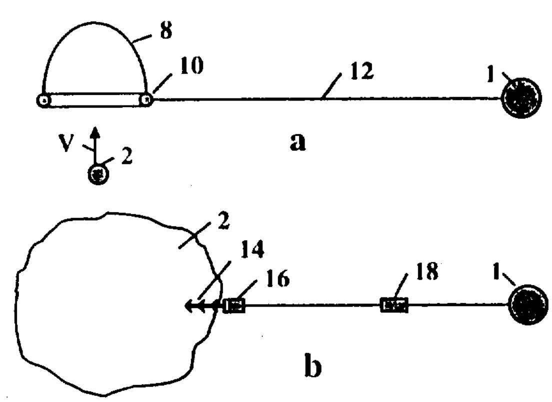

Fig.2. a) Catching a small asteroid by net; b) Connection to a big asteroid by anchor and cable. Notation: 8 - net, 10 - inflatable ring, 12 - cable (rope), 14 - anchor, 16 - spool, 18 - load cabin.

When the apparatus is at the shortest distance ***R*** from the space body, the apparatus connects to the space body (fig. 2b) by the anchor and the rope (see also fig. 3).

The apparatus rotates around the common gravity center on the angle φ with the angular speed ω and the linear speed ΔV . The cardioids of additional speed and direction of the apparatus is shown on fig. 4 (right side). The maximum additional velocity is $-2\Delta V=2(V_a-V_b)$, where V_a is apparatus velocity and V_b is the velocity of the space body. Fig. 4b shows the case where the space body moves in the opposite direction of the apparatus with velocity ΔV.

Fig.2a shows how a small asteroid (small meteorite) may be caught by a net. The net is positioned in the trajectory of a meteorite (small asteroid). The net is supported in an open position by the inflatable ring and connected to the space apparatus by the rope. The net catches the meteorite and transfers its kinetic energy to the space apparatus. The space apparatus changes its trajectory and speed and then disconnects from meteorite. If the asteroid is large, the astronaut team can use the asteroid anchor (figs.2b, 3).

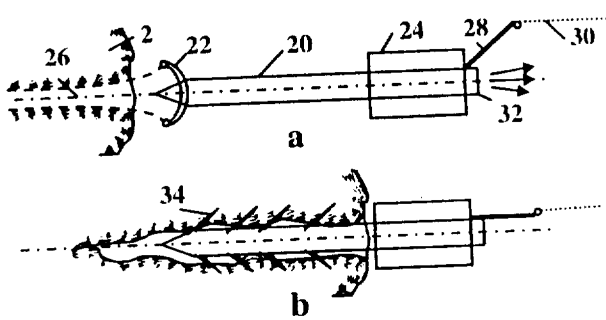

Fig.3. a) Anchor (harpoon fork). Notation: 20 - body; 22 - cumulative charge (shaped charge), 24 -rope spool, 26 - canal is made by shaped charge, 28 - rope keeper, 30 - rope, 32 - rocket impulse engine, which drives the anchor to asteroid, 34 - anchor catchers. **b**) Anchor connected to the asteroid.

The astronauts use the launcher (a gun or a rocket engine) to send the anchor (harpoon fork) to the asteroid. The anchor is connected to the rope. The anchor is launched into the asteroid and connects the space apparatus to the asteroid. The anchor contains the rope spool and a disconnect mechanism (fig.3). The space apparatus contains a spool for rope, motor, gear transmission, brake, and controller. The apparatus can include a container for delivering a load to the asteroid and back (fig.2b). One possible design of the space anchor is shown on the fig. 3. The anchor has a body, a rope, a cumulative charge (shared charge), the rocket impulse (explosive) engine, the rope spool and the rope keeper. When the anchor strikes the asteroid surface the cumulative charge burns a deep hole in the asteroid and the rocket-impulse engine hammers the anchor body into

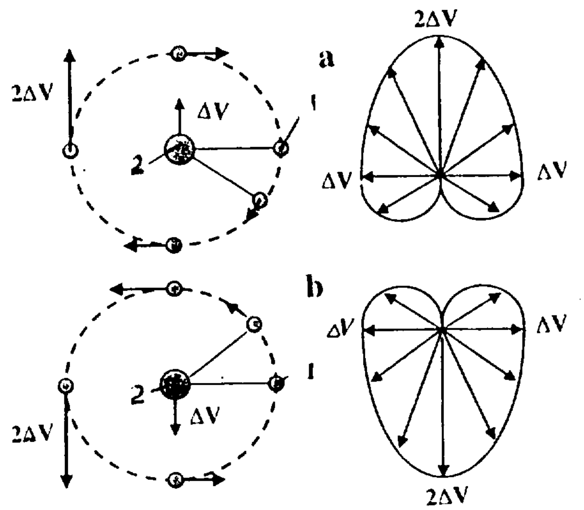

Fig.4. Using the kinetic energy of asteroid. Change the space ship trajectory (speed and direction) by employment of asteroids. In right side is cardioid of the additional velocity and its direction. The ship can get this velocity from asteroid. Notations: 40 -asteroid, 41- space ship, ΔV - difference between velocities of space ship and asteroid. a) Case when the asteroids has same direction as ship; b) case when asteroid has opposite direction ship as.

the asteroid. The anchor body pegs the catchers into the walls of the hole and the anchor's strength keeps it attached to the asteroid. When the apparatus is to be disconnected from the asteroid, a signal is given to the disconnect mechanism. If the asteroid is rotated with angular speed ω (fig.5), its rotational energy can be used for increasing speed and changing the trajectory of the space apparatus. The rotary asteroid spools the rope on its body. The length of the rope is decreased, but the apparatus speed is increased (see a momentum theory in physics).

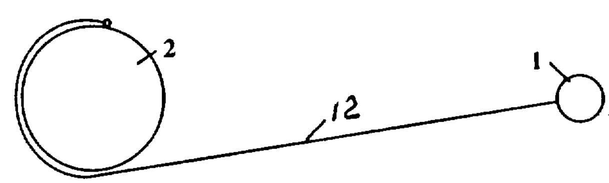

Fig.5. Using the rotary energy of a rotating asteroid.

The ship can change the length of cable. When the radius is decreased, the linear speed of the apparatus is increased. Conversely, when the radius is increased the apparatus speed is decreased. The apparatus can obtain energy from the asteroid by increasing the length of the rope from a centrifugal force.

The computations and estimations show the possibility of making this method a reality in a short period of time (see attached project).

An old space vehicle rotated around the Earth can also be used for increasing the speed of the new vehicle and for removing the old vehicle from orbit.

Theory of Asteroid Employment and Formulas for Computation

(known or developed by author)

1. Cable equal stress

$$a(R)=A/A_o=exp(V^2/2k) = exp(\omega^2R^2/2K). \quad (16)$$

2. Mass of cable

$$W=A_o\gamma\int_0^R a(r)dr=F_o/k\int_0^R exp(\omega^2r^2/2r)dr. \quad (17)$$

3. Relative cable mass is

$$W_r=B/(1+B), \quad B=(n/k)\int[exp(ng/V)^2r^2/2k]dr, \quad (18)$$

where the integration interval is $[0, V^2/ng]$, n is overload, V is circle apparatus speed about common center of gravity.

4. Circular velocity of ship around asteroid

$$R=V^2/gn, \quad V=(gnR)^{0.5}. \quad (19)$$

Computations are represented in Fig.6-8.

5. Relative mass of cable with constant cross-section area for small speed

$$W_r=W/W_s=\gamma V^2/\sigma g_o. \quad (20)$$

6. Additional velocity space vehicle receives from asteroid

$$\Delta V= V_a(1+\cos\varphi), \qquad \varphi=\varphi_1+\varphi_2, \quad (21)$$

where V_a has sign "-" if an asteroid moves in opposite direction to a ship.

6. The known formulas below may be useful:

$$V=\omega R; \quad V_3R_3=V_4R_4; \quad V_1=R_o(g_o/R)^{0.5};$$
$$V_2=V_1(2)^{0.5}; \quad R_g=(g_oR_o^2/\omega^2)^{1/3}. \quad (22)$$

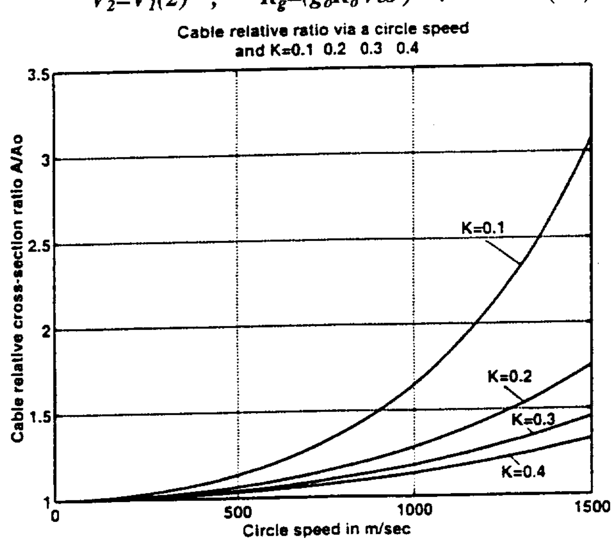

Fig.6. Asteroid cable relative ratio via a circle speed and coefficient K = 0.1 –0.4.

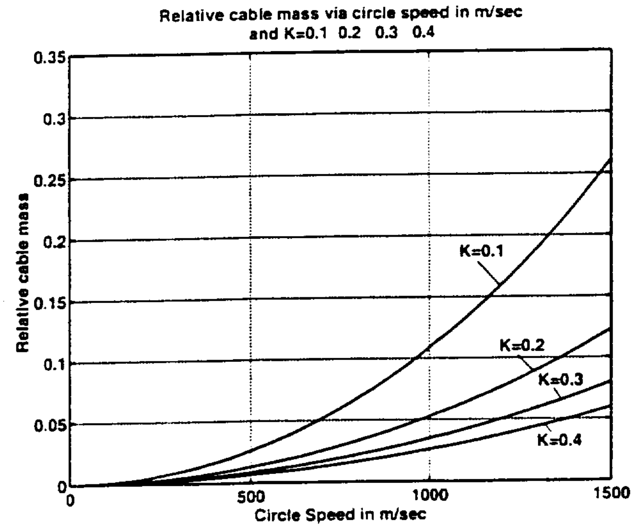

Fig.7. Relative cable asteroid mass via circle speed in m/sec and coefficient K = 0.1 -.0.4

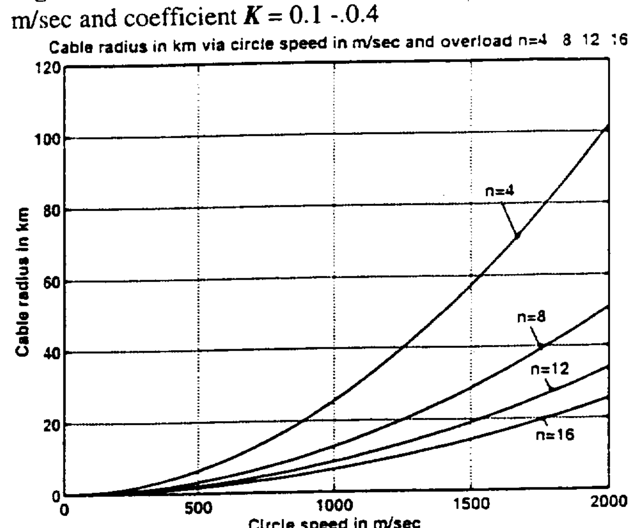

Fig.8. Cable radius in km via circle speed in m/sec and overload n = 4 – 16.

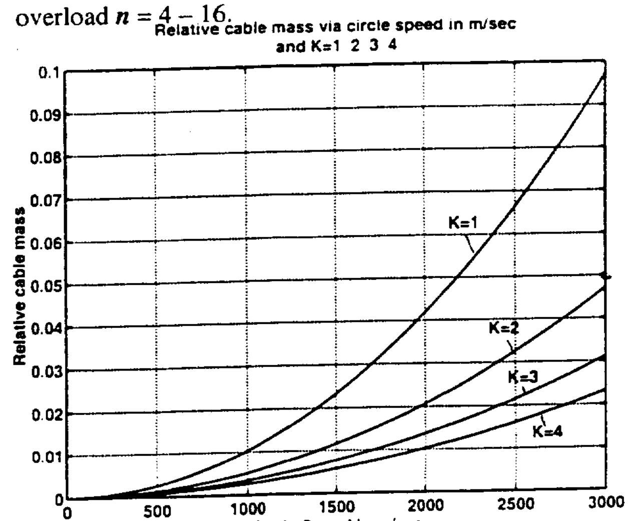

Fig.9. Asteroid cable relative ratio via a circle speed and coefficient K = 1 – 4.

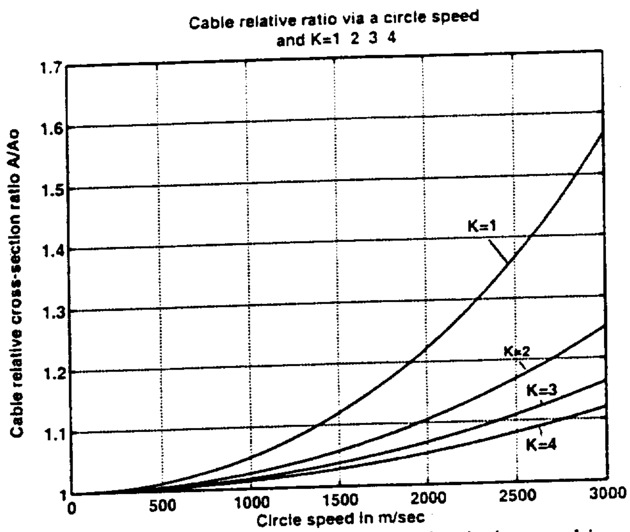

Fig.10. Relative cable asteroid mass via circle speed in m/sec and coefficient K = 1 - 4

Project.

Using asteroids for changing trajectory and speed of Space Apparatus (ships, probes)

The capability to change the trajectory and speed of a space vehicle by an asteroid is shown on fig. 4. The space ship could obtain a maximum additional speed equal to two times the speed difference between the space vehicle and the asteroid (speed of asteroid about space ship). If the length of the connection cable is changed, the speed of the space ship could change by more than double the speed difference. If the asteroid is rotating, the space ship can also obtain an additional speed increased from the rotation. The additional speed from one asteroid is also limited (for a manned ship) by the mass of the cable. For an additional speed of 1,000 m/sec and K=0.2, the mass of cable would equal 5% of the mass of the space apparatus. For an additional speed of 2,000 m/sec, the mass of cable would equal 23% of the mass of the space apparatus. For travel to an asteroid, a connection device must be mounted to the main cable. The cable may be used multiple times.

The results of computation for different cases are shown in Figs.6-10. If change of ship speed is less then 1,000 m/sec, the conventional widely produced fiber (admissible K=0.1) can be used. The cable mass is about 11% from ship mass. After disconnection the cable will be spooled and can be used again. The reader can make the estimation for other cases. The asteroids can be located by radio or optical devices at thousands of kilometers. Their speed, direction of flight and mass can be computed. The ship (probe) can make small corrections to its own trajectory, get the required position about the asteroid. All big asteroids having diameter over one kilometer (more than 6000) are in astronautical catalogs and their trajectories are well known. One thousand of them are located near the Earth. For those, we can compute in advance the intercept parameters. At the present time, a long-range space apparatus uses the gravity of a planet to change its trajectory. However, the Sun has only nine planets, and they are located very far from one another. The employment of asteroids increases this possibility a million times over.

Discussing

Estimation of probability to meet asteroid or meteorite. It is known that every day about one ton of meteorites having a mass greater then 8 kg fall into the Earth's atmosphere. The Earth's surface is about 512 millions km^2. If average mass of meteorite is 10 kg, it means, 100 meteorites per day or one meteorite a day per every 5 millions km^2. If space probe has a mass about 100 kg, a 10 kg meteorite has enough mass to change the direction and speed of a space probe. Ground locators can detected a one kg space mass at a distance up to thousands km. If the space ship can detect range of one thousand km, it means it can see a space body with an area of one million km^2 or about one meteorite in every 5 days. If one meteorite in ten is suitable for employment, it means every 50 days the space apparatus will meet an eligible meteorite near the Earth. This possibility is tens times greater in the asteroid belt between Mars and Jupiter. For 6,000 big asteroids, we can compute the intercept parameters now. I expect this number will increase as we register more small asteroids.

There are about 8,000 fragments of old rockets and space equipment near Earth. The trajectories of those are known. They also can be used for accelerating the space apparatus. In this case we will have double benefit: to accelerate current space apparatus and remove space garbage from the Earth's atmosphere (or outer space). This space garbage is dangerous for current ships and this problem will increase every year.

Note that the kinetic energy of space bodies may be used if the space body has a DIFFERENT speed or direction. It is difficult to use a tether system (for example, last stage of rocket and Shuttle ship) because they have the same speed and direction.

Cable Problem. If the required change of speed is less then 1,000 m/sec, then cable from current artificial fibers can be used. Twenty years ago, the mass of the required cable would not allow this proposal to be possible for additional speed more 2,000 m/sec from one asteroid. However, today's industry widely produces artificial fibers which have tensile strength 3-5 times more than steel and density 4-5 times less then steel. There are experimental fibers which have tensile strength 30-60 times more than steel and density 2 to 4 times less than steel. For example, in the book "*Advanced Fibers and Composites*", (Francis S.

Galasso, Gordon and Branch Science Publisher, 1989, p.158), there is a fiber C_D with tensile strength H=8000 kg/mm^2 and density (specific gravity) D=3.5 g/cm^3. If we take an admitted strength of 7000 kg/mm^2 (H=7x10^{10} n/m^2, D=3500 kg/m^3) then the ratio, D/H=0.05x10^{-6} or H/D=20x10^6 (K=2). Although (1976) the graphite fibers are strong (H/D=10x10^6), they are at best still ten times weaker than theory predicts.

Steel fiber has tensile strengths 5,000 MPA (500 kg/sq.mm), the theoretic value is 22,000 MPA (1987). The polyethylene fiber has a tensile strength 20,000 MPA and the theoretical value is 35,000 MPA (1987).

The mechanical behavior of nanotubes is also exciting because nanotubes are seen as the ultimate carbon fiber, which can be used as reinforcements in advanced composite technology. Early theoretical work and recent experiments on individual nanotubes (mostly MWNT's) have confirmed that nanotubes are one of the stiffest materials ever made. Whereas carbon-carbon covalent bonds are one of the strongest in nature, a structure based on a perfect arrangement of these bonds oriented along the axis of nanotubes would produce an exceedingly strong material. Traditional carbon fibers show high strength and stiffness, but fall far short of the theoretical in-plane strength of graphite layers (an order of magnitude lower). Nanotubes come close to being the best fiber that can be made from graphite structure.

For example, whiskers made from Carbon nanotubes (CNT) have a tensile strength of 200 Giga-Pascals and Young's modulus of over 1 Tera Pascals (1999). The theory predicts 1 Tera Pascals and Young modules 1-5 Tera Pascals. The hollow structure of nanotubes makes them very light (a specific density varies from 0.8 g/cc for SWNT's up to 1.8 g/cc for MWNT's, compared to 2.26 g/cc for graphite or 7.8 g/cc for steel).

Specific strength (strength/density) is important in the design of our Transportation System and space elevator; nanotubes have a specific strength at least 2 orders of magnitude greater than steel. Traditional carbon fibers have specific strength 40 times that of steel. Where nanotubes are made of graphite carbon, they have good resistance to chemical attack and have high terminal stability. Oxidation studies have shown that the onset of oxidation shifts by about 100^0 C to higher temperatures in nanotubes compared to high modulus graphite fibers. In vacuum or reducing atmospheres, nanotubes structures will be stable to any practical service temperature. Nanotubes also have excellent conductivity, similar to copper.

The price of whiskers SiC produced Carborundun Co. with σ=20,690 MPa, γ=3.22 g/cc was 440 $/kg in 1989. The medical, environmental, space, aviation, machine-building, and computer industries all need cheap nanotubes. Some American companies plan to produce nanotubes in 2-3 years.

Below the author provides a brief overview of the annual research information (2000) regarding the proposed experimental test fibers.

Data that can be used for computation

Let us consider the following experimental and industrial fibers, whiskers, and nanotubes:

1. Experimental nanotubes CNT (Carbon nanotubes) have tensile strength 200 Giga-Pascals (20000 kg/sq.mm), Young's modules is over 1 Tera Pascal, specific density γ=1800 kg/m^3 (1.8 g/cc)(2000 year).

   For safety factor n=2.4, σ=8300 kg/mm^2=8.3x10^{10} n/m^2, γ=1800 kg/m^3, (σ/γ)=46x10^6, K=4.6. The nanotubes SWNT's have density 0.8 g/cc, the nanotubes MWNT's have the density 1.8 g/cc. About 300 kg of nanotubes will be produced in the USA in 2002 (see Newsletter Chim.& Eng., Oct.8, 2001).
2. Whiskers C_D has σ=8000 kg/mm^2, γ=3500 kg/m^3 (1989) [3, p.158].
3. Industrial fibers have σ=500 - 600 kg/mm^2, γ=1800 kg/m^3, σ/γ=2,78x10^6, K=0.278 – 0.333,

Properties for some other experimental whiskers and industrial fibers are shown in Table #1.

Table#1

Material Whiskers	Tensile strength kg/mm^2 or GPa	Density g/cc	Fibers	MPa	Density g/cc
AlB_{12}	2650	2.6	QC-8805	6200	1.95
B	2500	2.3	TM9	6000	1.79
B_4C	2800	2.5	Thorael	5650	1.81
TiB_2	3370	4.5	Allien 1	5800	1.56
graphite	1.97 GPa	1.67	Allien 2	3000	0.97
SiC	13,8-41.4 GPa	3.22			

Reference [3]-[6].

Conclusions

The availabilities of both current and new materials makes the suggested propulsion system and projects highly realistic for a long trip to outer space with minimum expenditure of energy. The same idea was used in the research and calculation of other revolutionary innovations such as: launches to Space without rockets (not space elevator, not gun); cheap delivery of loads from one continent to another across space; cheap delivery of fuel gas over long distance without steel tubes or damage to environment; low cost delivery of large load flows across sea streams and mountains without bridges or underwater tunnels [Gibraltar, English Channel, Bering Stream (USA-Russia), Russia-Sakhalin-Japan, etc.]; new economical Transportation Systems; getting inexpensive energy from air streams at high altitudes; etc. Some of them are presented in [7]-[15].

The author has developed novel ideas and related computations for the above mentioned problems. Even though these projects may seem impossible using the current technology, the author is prepared to discuses project details with serious organizations with similar research and development goals.

Patent Applications are 09/789,959 of 02/23/01; 09/873,985 of 6/4/01; 09/893,060 of 6/28/01; 09/946,497 of 9/6/01; 09/974,670 of 10/11/01; 09/978,507 of 10/18/01.

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